

Observations from *Hinode* and *SDO* of a Twisting and Writhing Start to a Solar-filament-eruption Cascade

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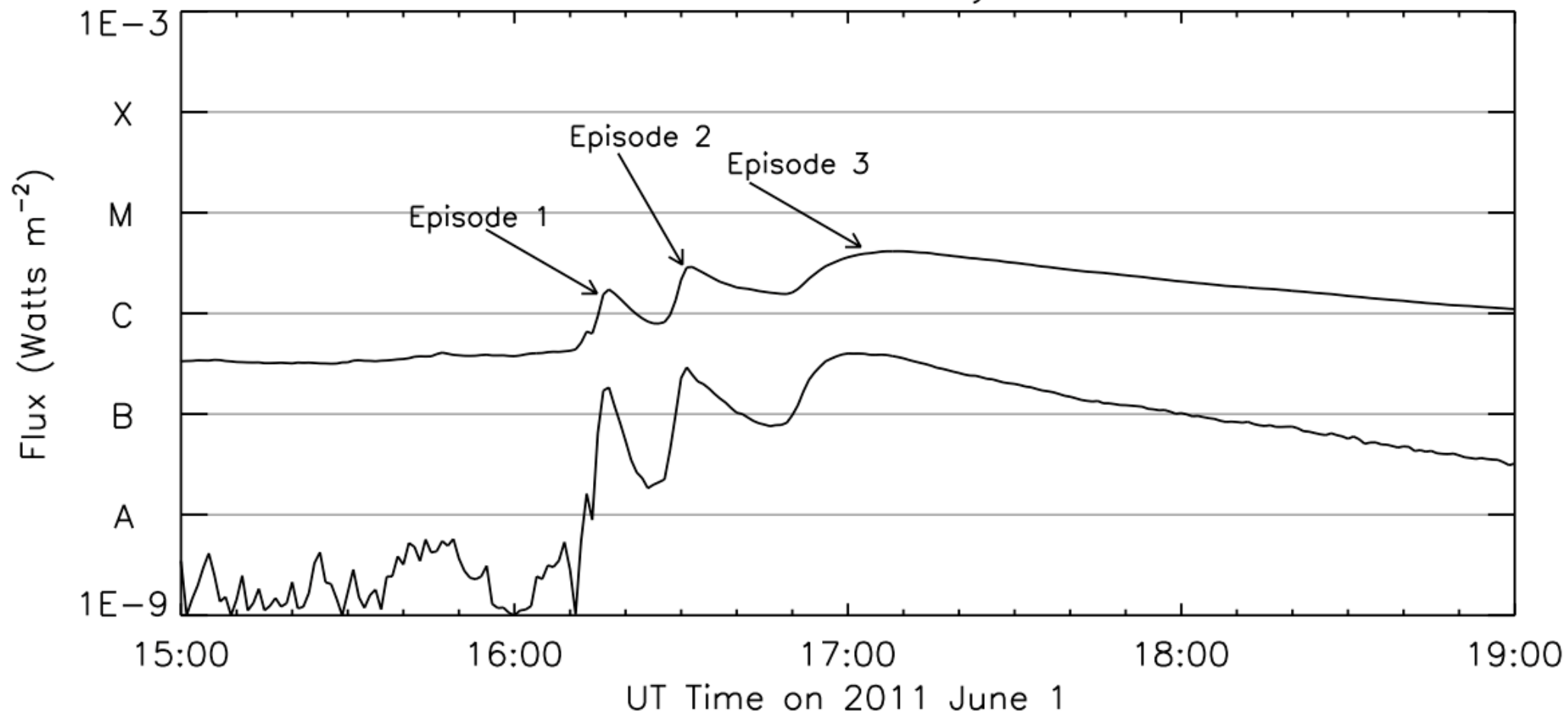
An AR Ejective Eruption from SDO and Hinode

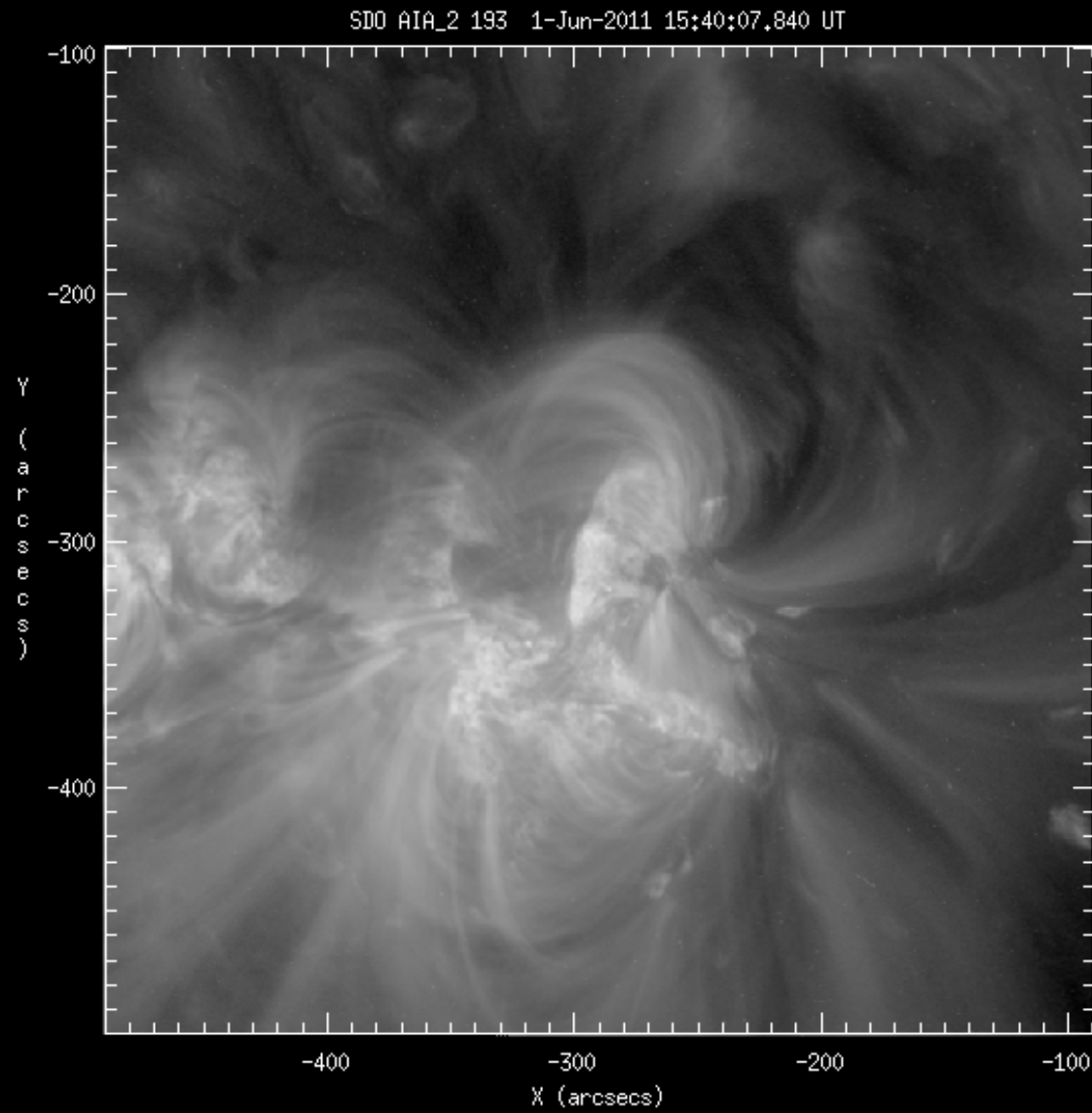
- ♦ Active region eruption of 1 June 2011.
- ♦ Ejective eruption.
- ♦ GOES class C4.1 flare.
- ♦ SDO/AIA, various filters (94, 131, 171, 193, 211, 304, 335 Ang.)
- ♦ High time cadence (24 s) and high spatial resolution (0".6 pixels).
- ♦ SDO/HMI line-of-sight magnetograms.
- ♦ Hinode observed the **onset**, and the later decay phase.

We will: Overview the full eruption sequence.

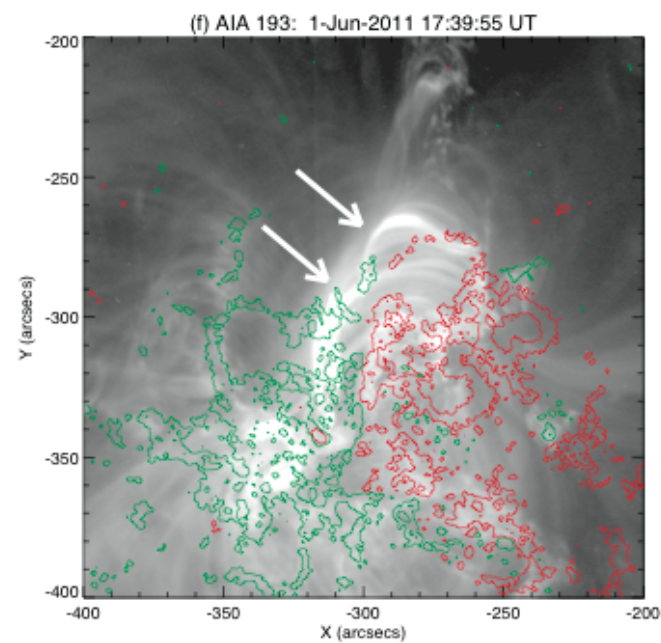
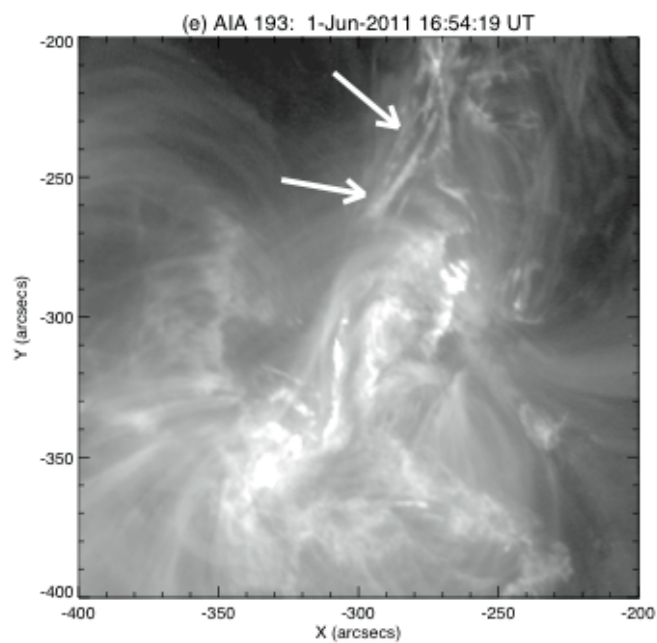
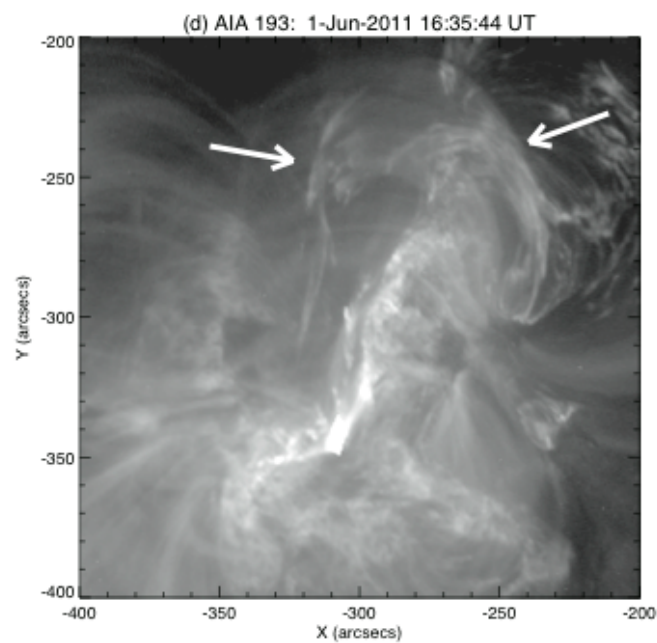
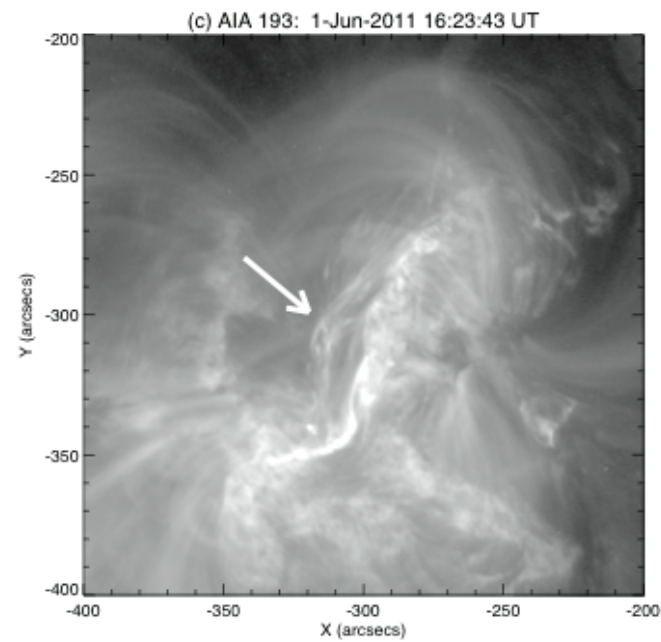
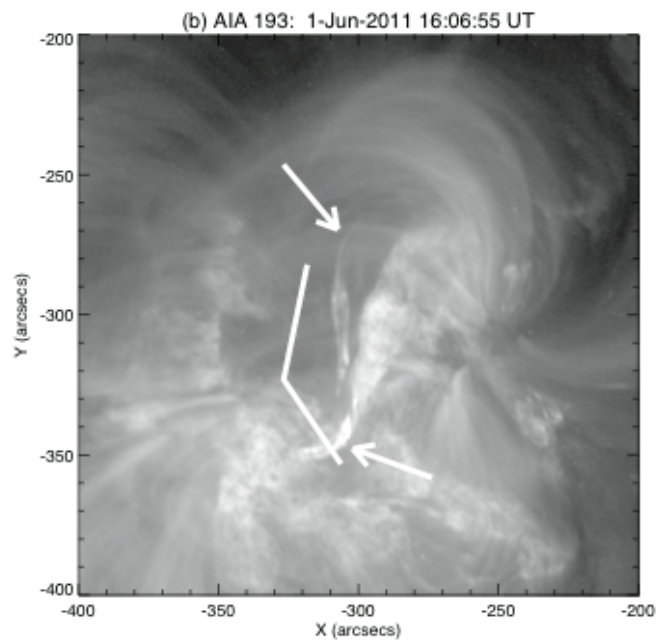
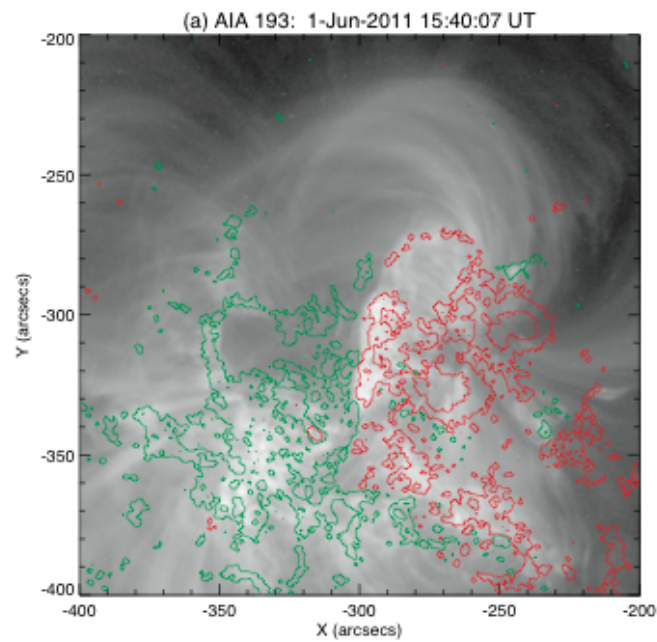
Main focus: What is going on in the onset phase?

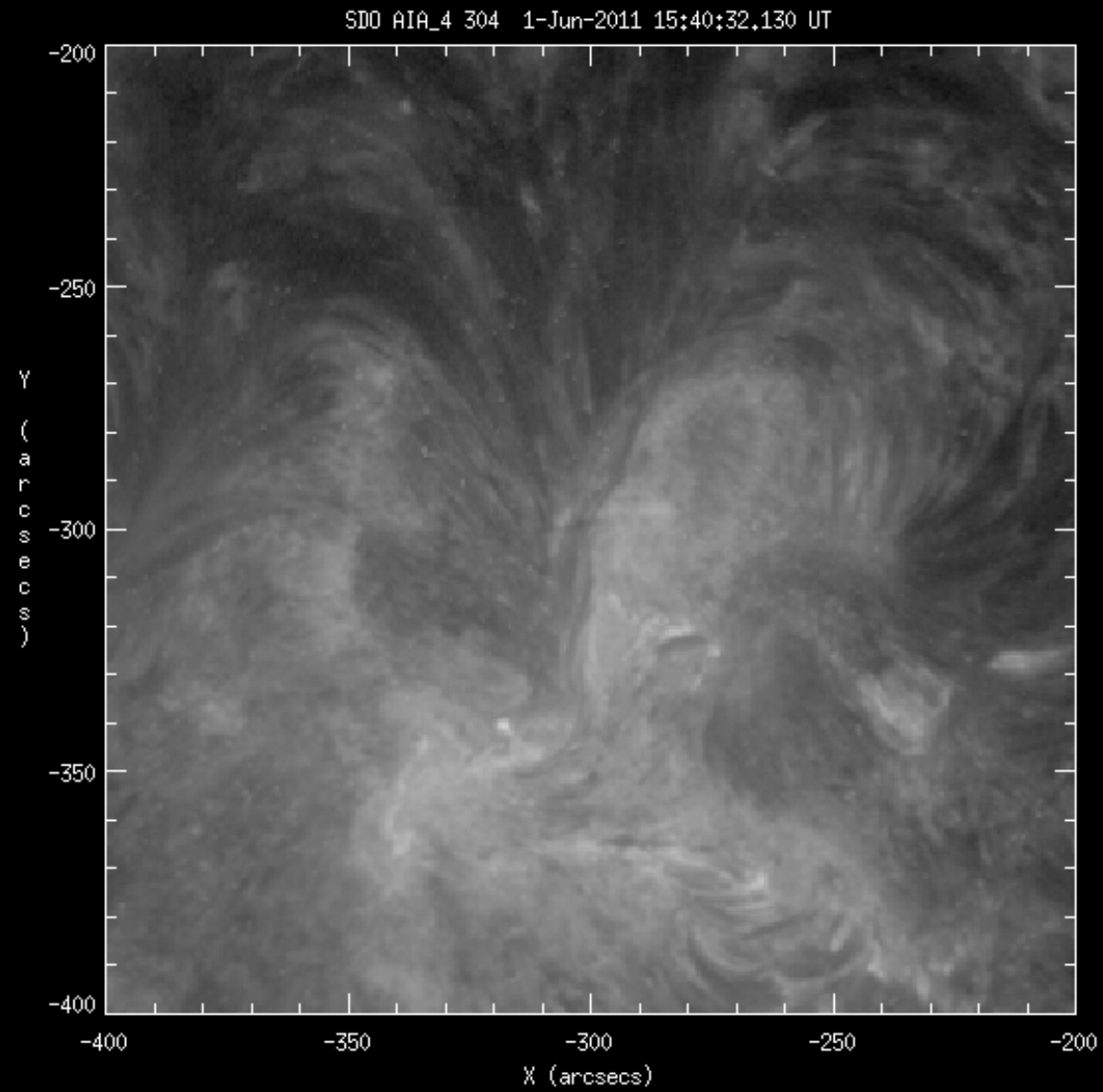
GOES 15 X-Rays:



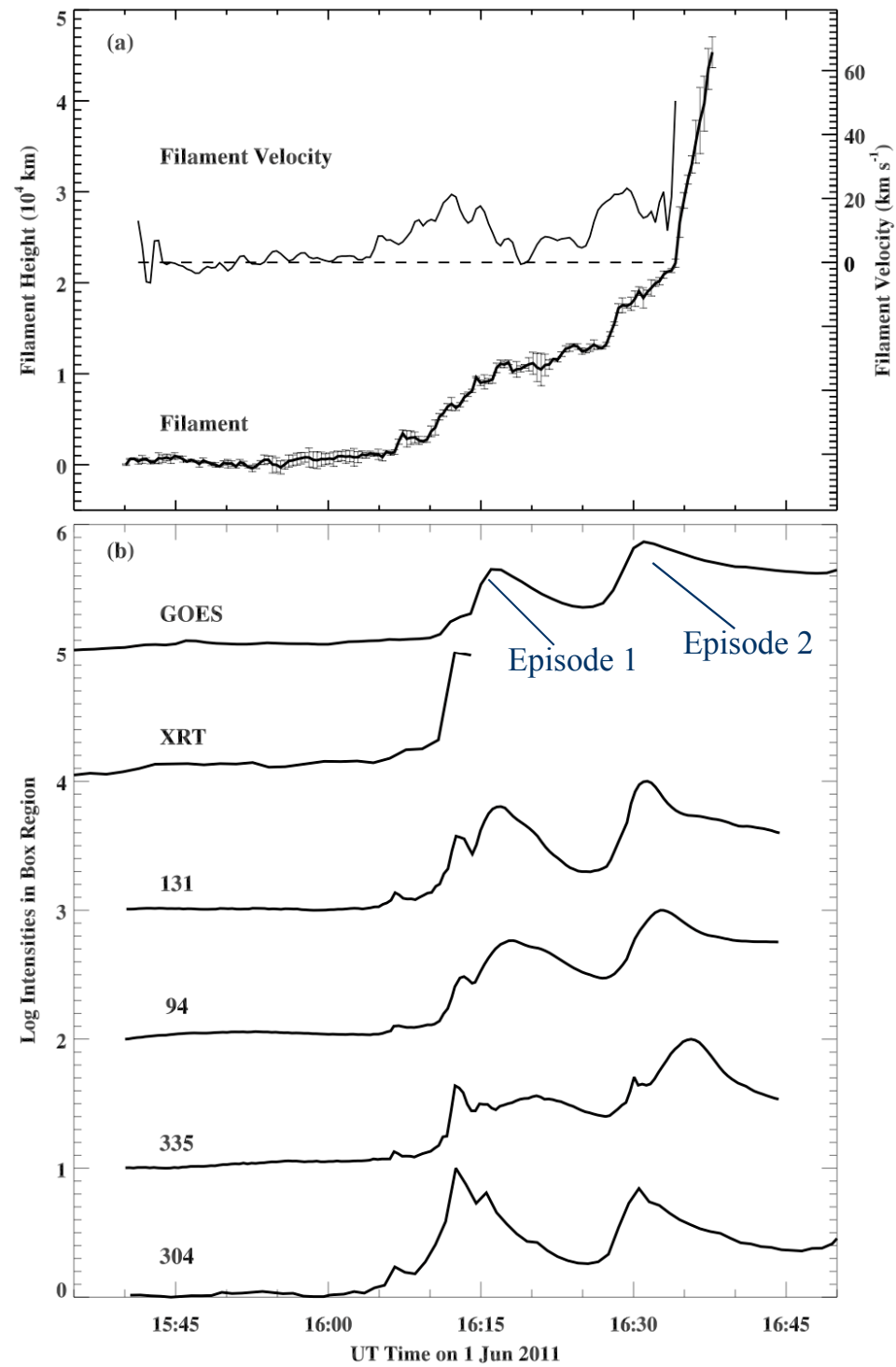


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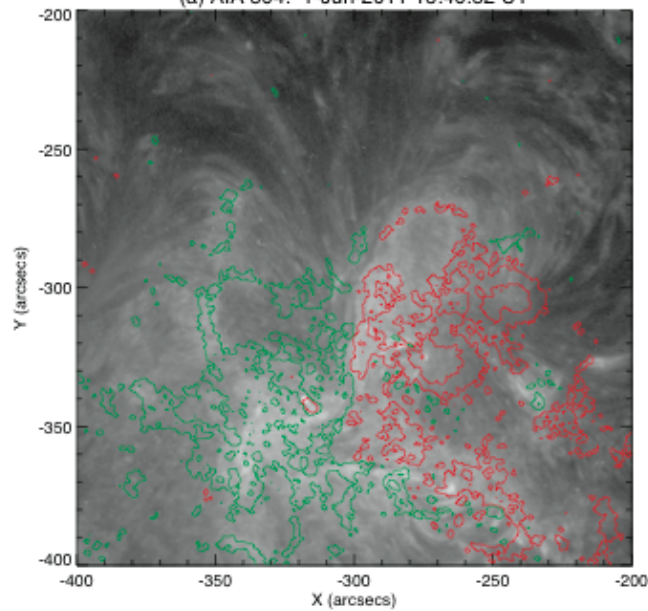
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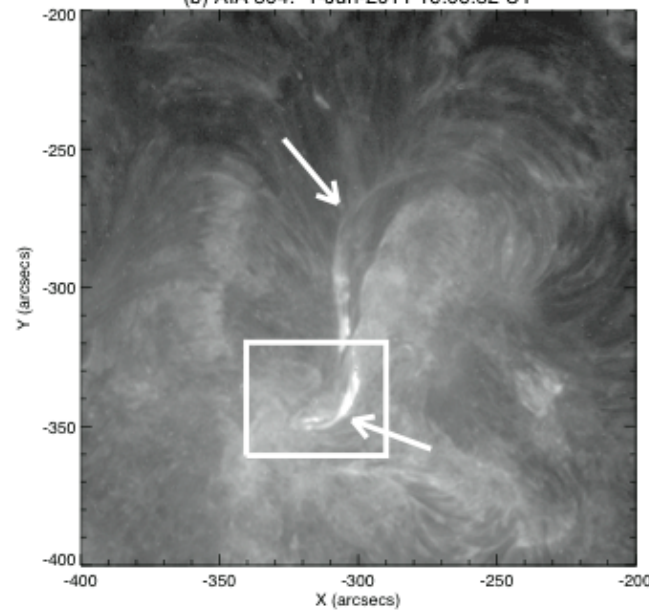
- There are two filament eruptions (filament 1 and filament 2).
- Filament 1 has slow rise with steps, as in several previous cases. GOES “episodes” play role of “microflares” in other events; that is, filament jumps $\Leftrightarrow$ intensity peaks.
- Episode 1 brightening: Accompanied by filament 1’s initial motions. (Rest of talk.) Filament 1 becomes unstable, and...
- Episode 2 brightening: Flare ribbons following filament 1’s fast liftoff. This destabilizes neighboring filament 2, and...
- Episode 3 brightening: Flare ribbons of whole system following filament 2’s eruption.

What goes on at the southern end, near time of Episode 1 brightening?

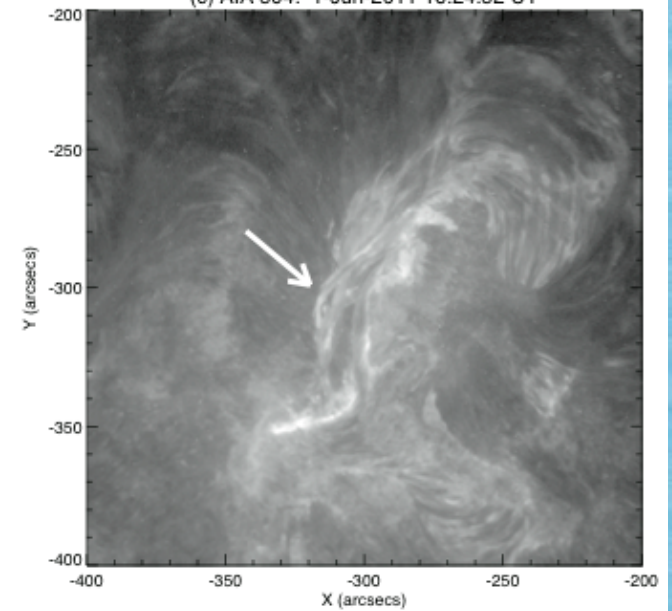
(a) AIA 304: 1-Jun-2011 15:40:32 UT



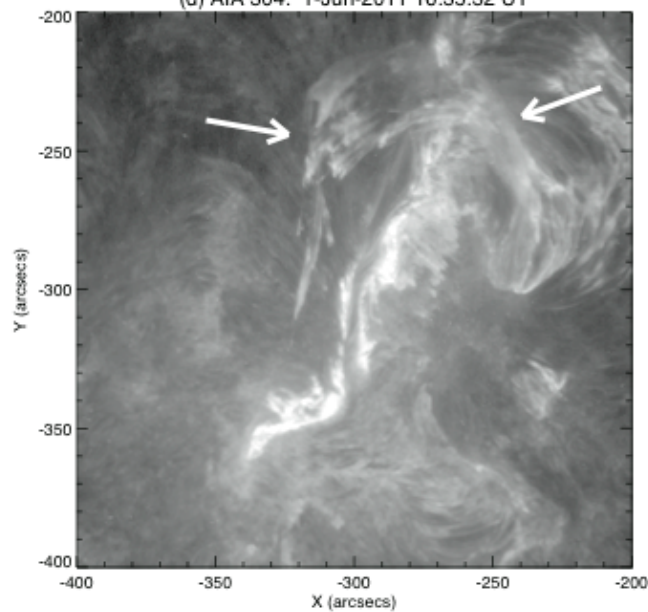
(b) AIA 304: 1-Jun-2011 16:06:32 UT



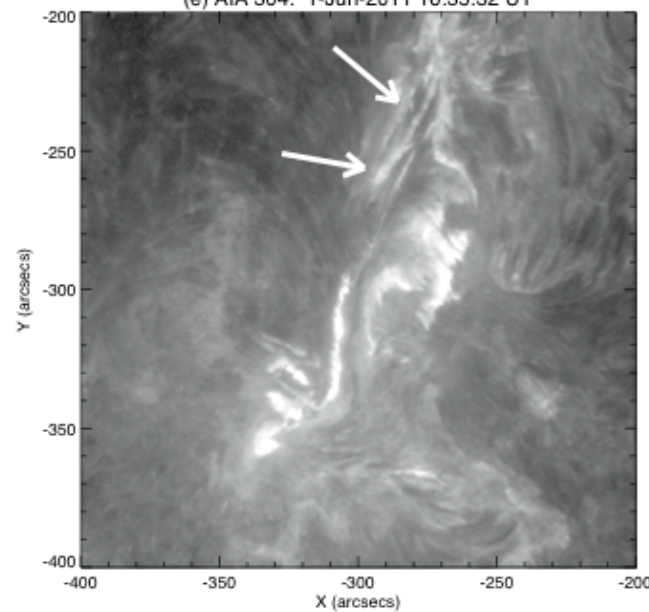
(c) AIA 304: 1-Jun-2011 16:24:32 UT



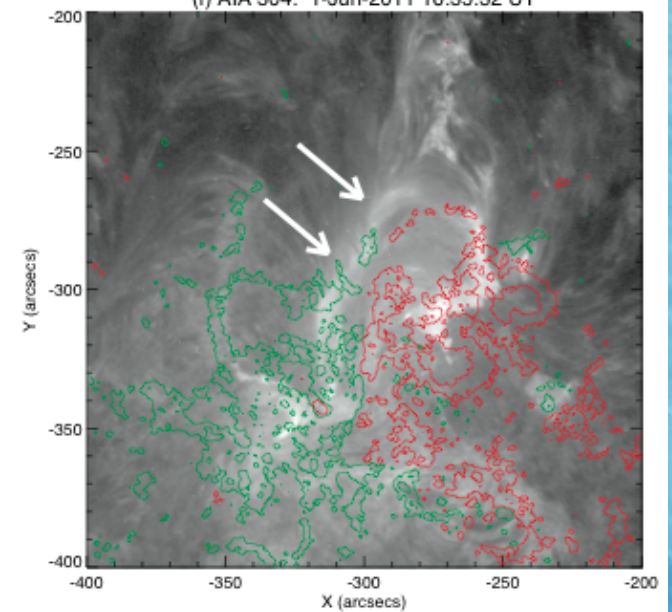
(d) AIA 304: 1-Jun-2011 16:35:32 UT

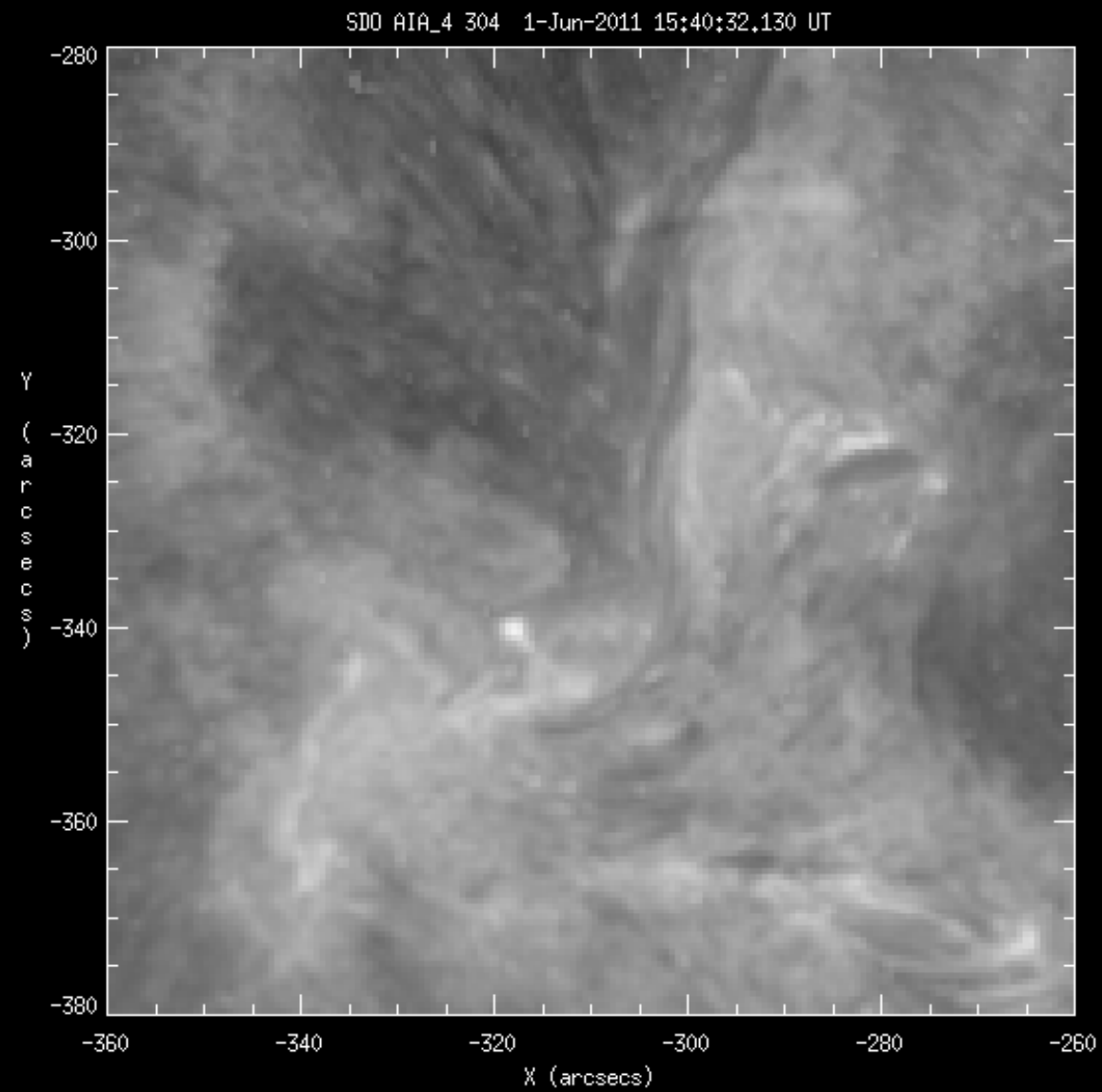


(e) AIA 304: 1-Jun-2011 16:35:32 UT

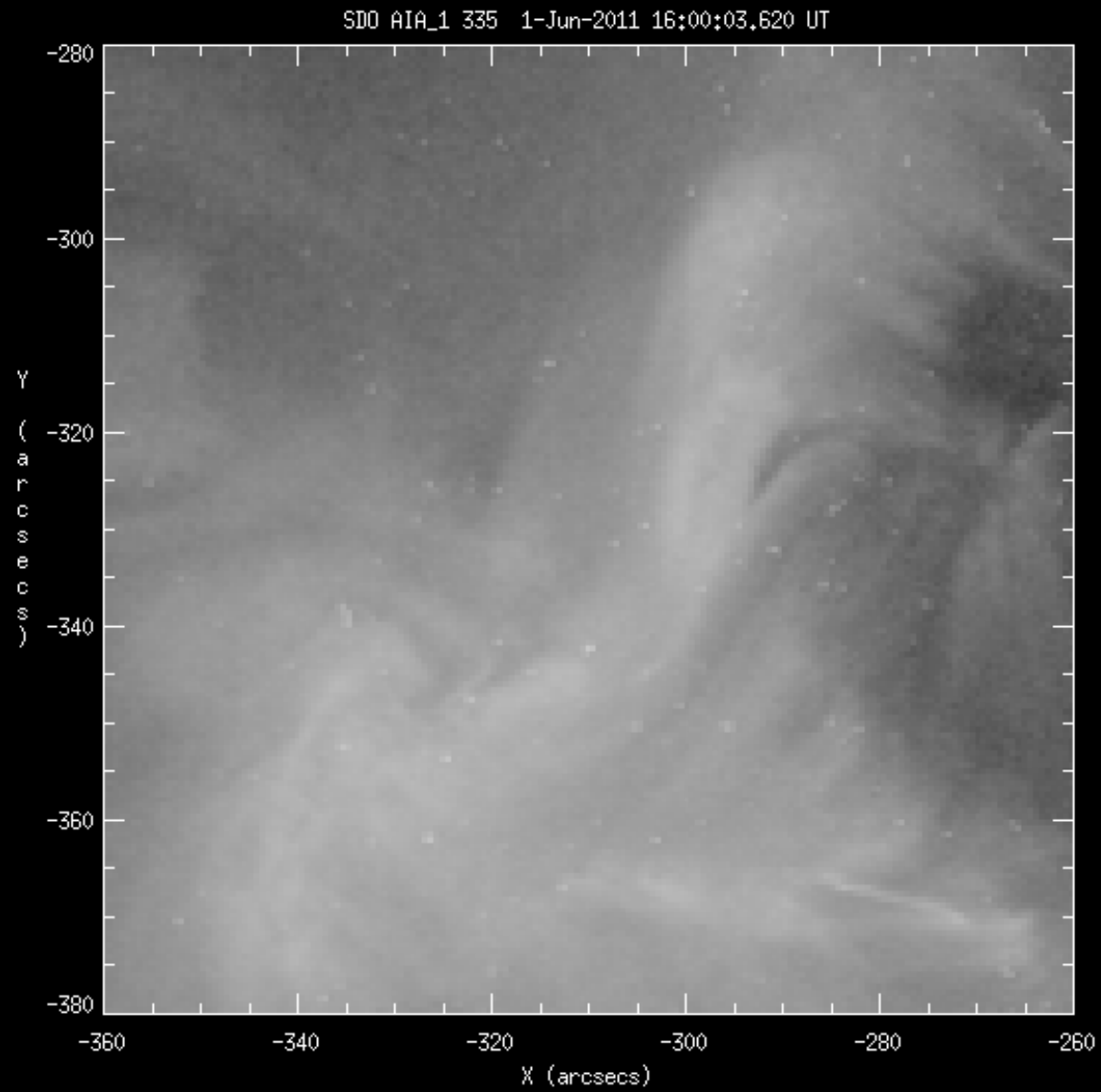


(f) AIA 304: 1-Jun-2011 16:35:32 UT

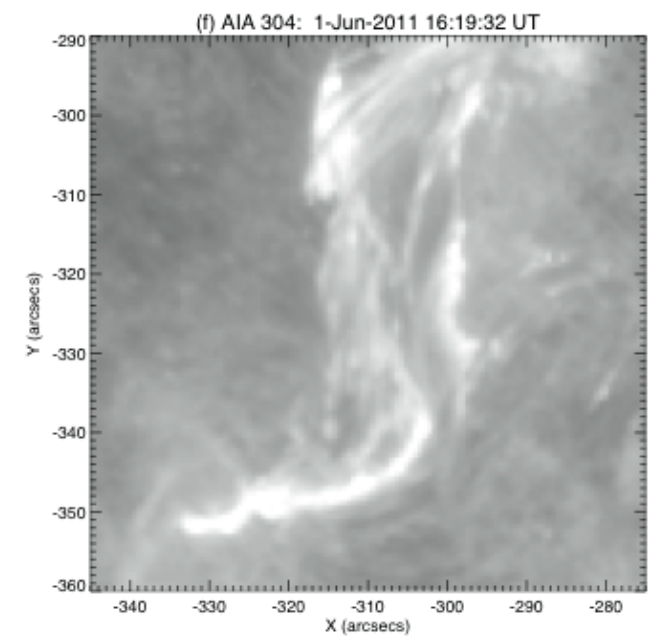
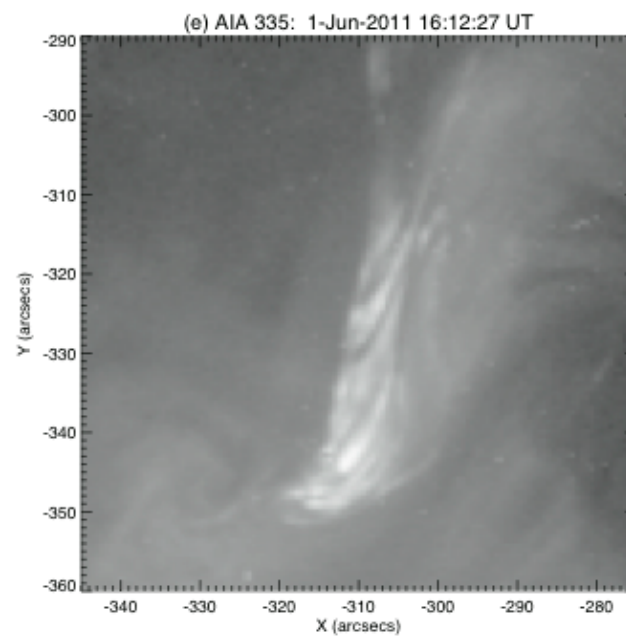
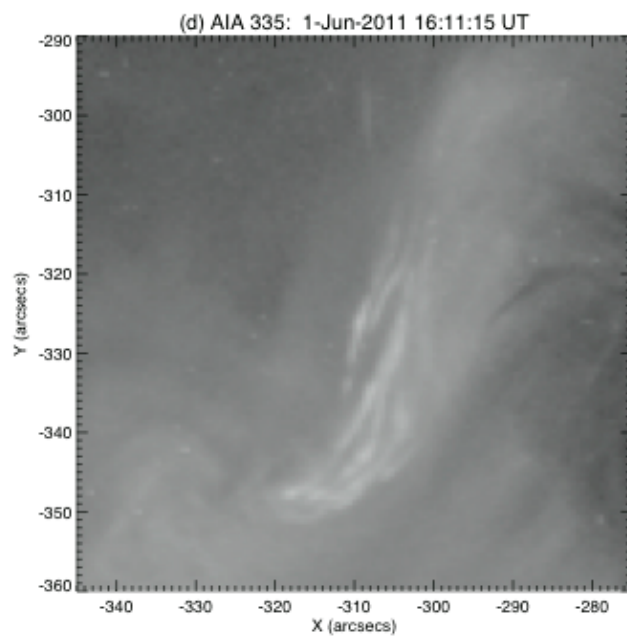
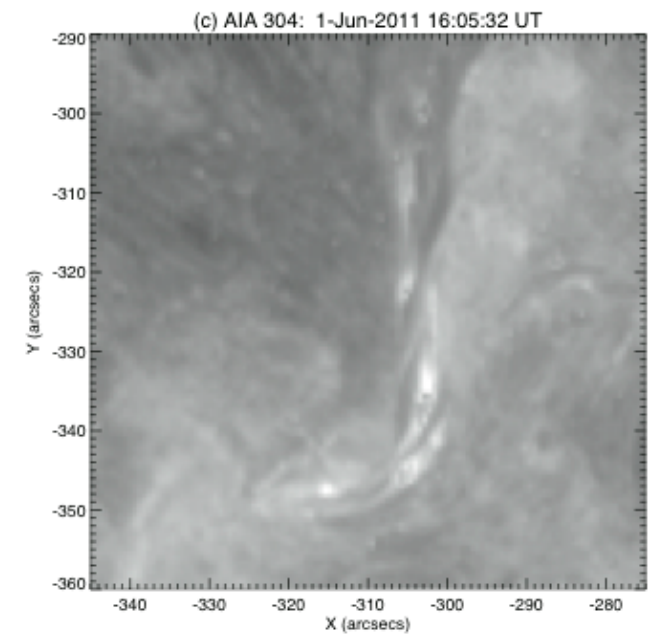
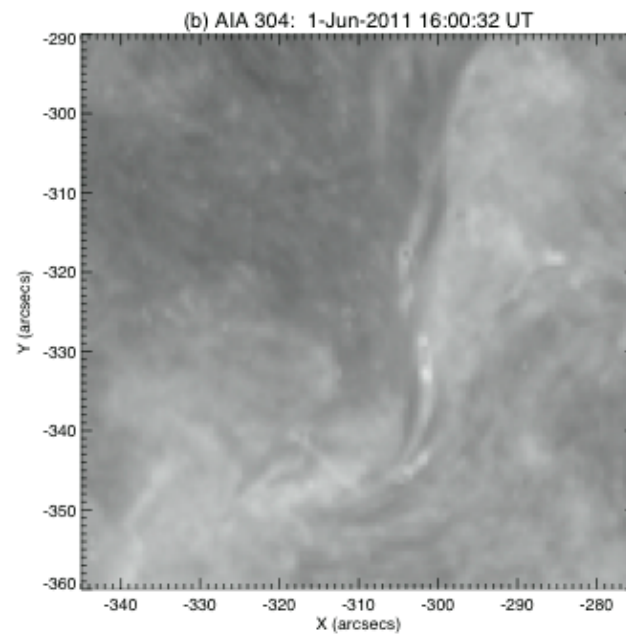
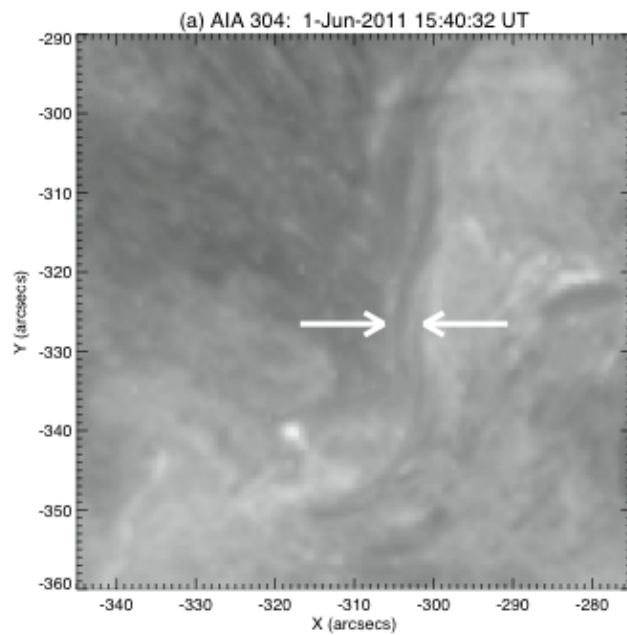


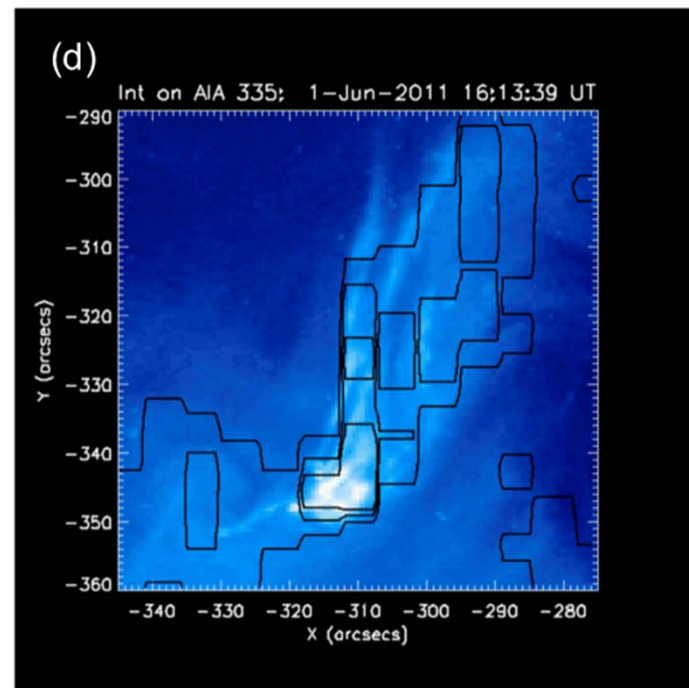
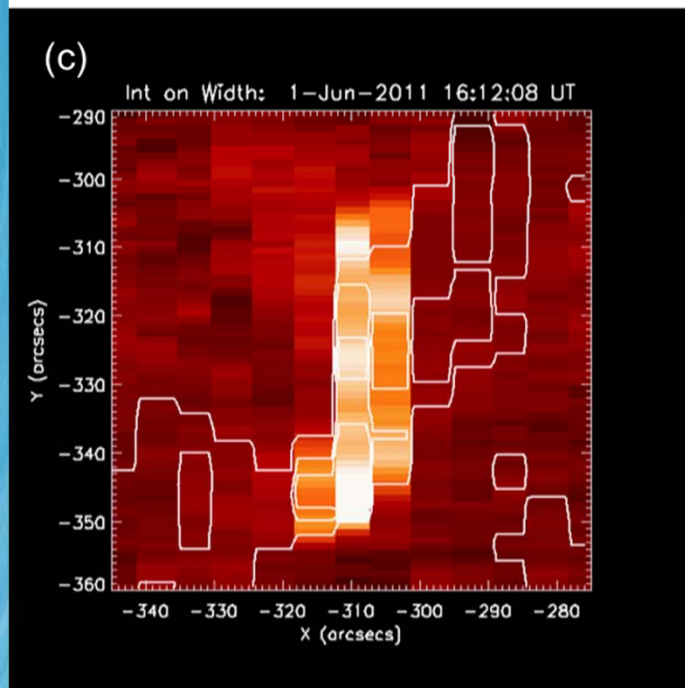
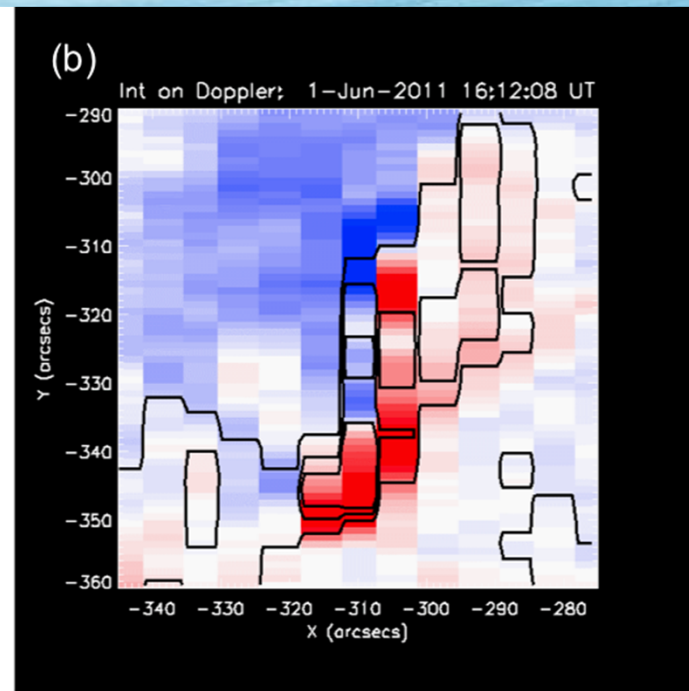
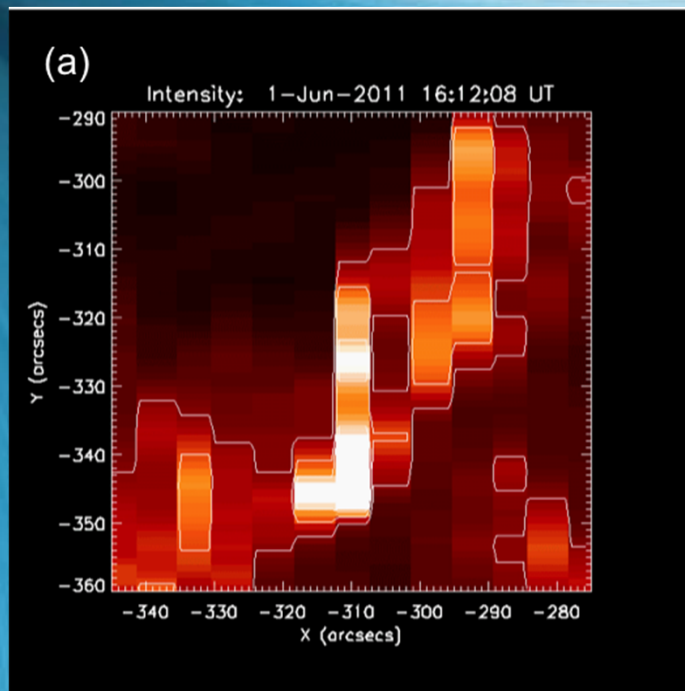


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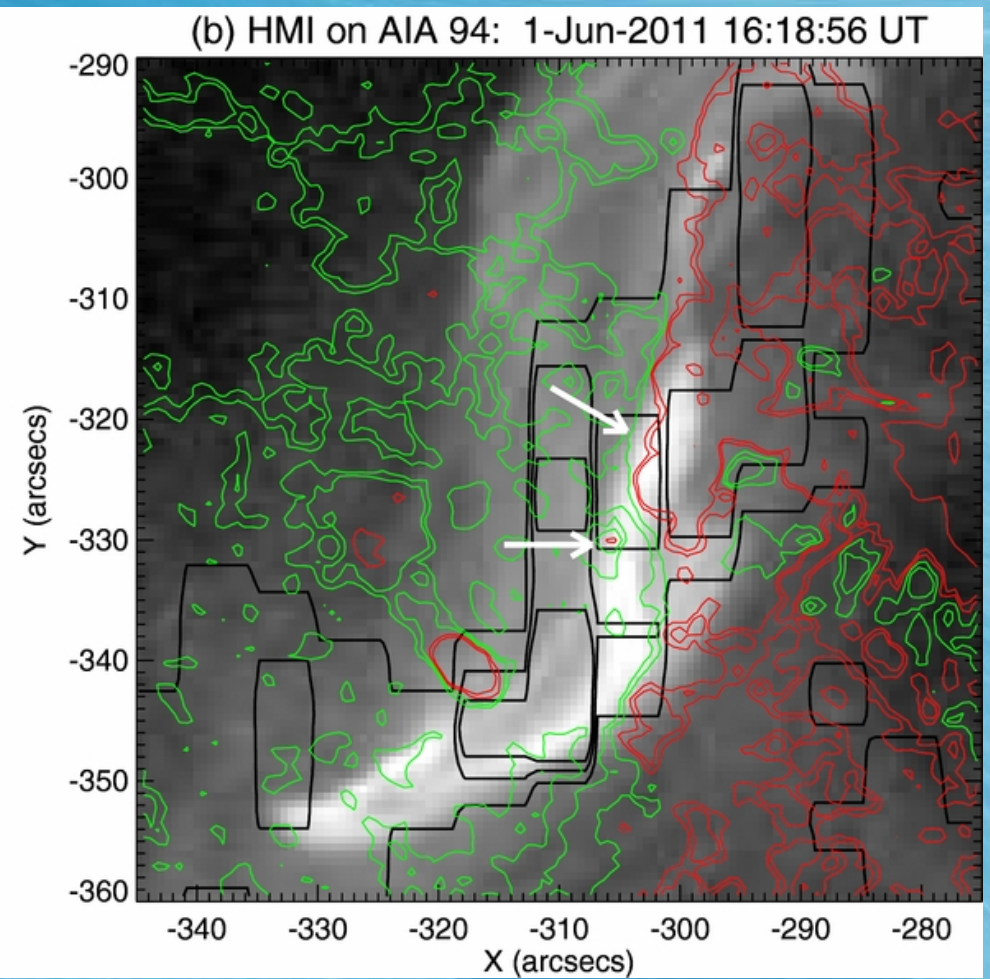
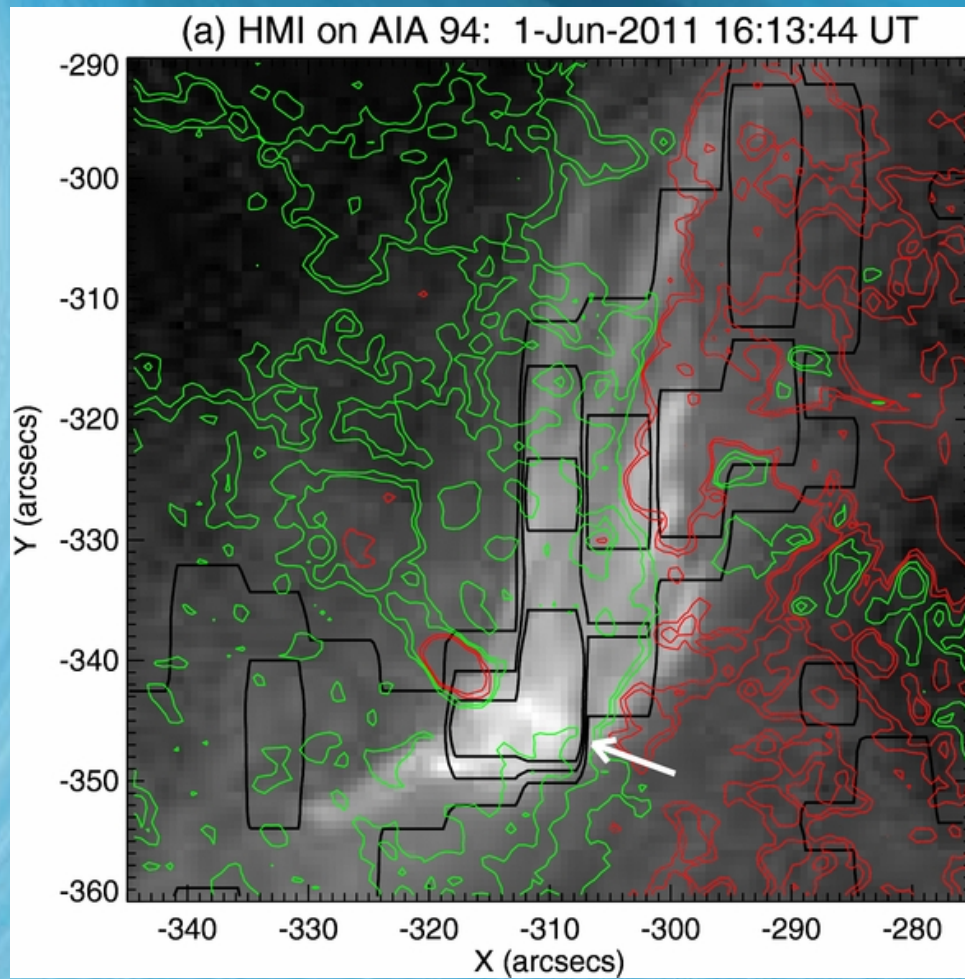
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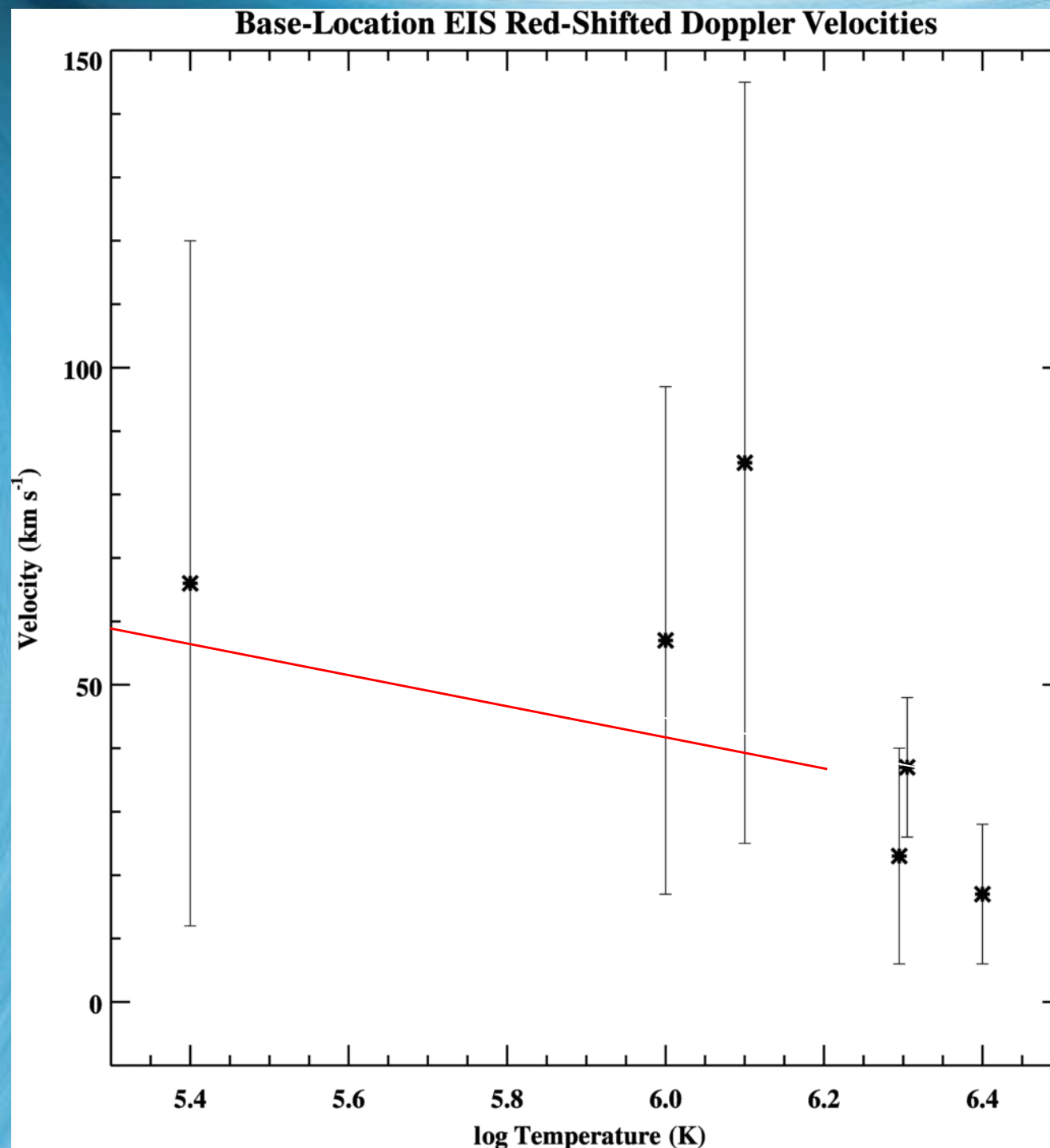




EIS Spectral Properties

- ◆ “Picket fence” mode; 1” in N-S, ~6” in EW
- ◆ Slit crosses ROI ~ 16:13:36 UT
- ◆ Alignment good to ~3”, based on intensity matching
- ◆ Doppler velocities:
 - ◆ Max blue in E strip ~ 23+-17 km/s
 - ◆ Max red in S, ~ 85+-60 km/s
 - ◆ Max red in W strip ~ 62+-25 km/s
- ◆ Non-thermal velocities:
 - ◆ ~ 70 km/s in two strips
 - ◆ ~ 125 km/s in s
 - ◆ These max are similar to C- and M-flares of Kay et al. (2006)
- ◆ What leads to blue and red Doppler shifts?
 - ◆ Not twisting....
 - ◆ Maybe “flare” loops?





Red= Milligan
& Dennis (2009),
Evaporation red
shift.

Is the “Flux Rope” Structure Twist-Unstable?

Some history of twist-induced instability in filament eruptions:
e.g., Sakurai, Török & Kliem, Fan & Gibson, Gilbert et al.,
van Driel-Gesztelyi et al.

Criterion : Kink instability for line-tied tube (Hood & Priest): 2.5π ;
for Titov & Démoulin loop (Török et al): $\sim 3.5\pi$

We observe here: ~ 1.5 turns (3.0π) over $\sim 50''$
 $\Rightarrow$ consistent with kink instability acting.

(Cf. Srivastava et al. (2010): Small flare seen in TRACE and
Hinode: $\sim 6.0\pi$)

Can this drive the entire eruption sequence?

Estimate amount of free energy in newly-twisted field (cf. Moore 1988):

$$B_{norm} \approx B_{par}$$

$$E_{free} \sim B_z^2 / 8\pi \times (\pi r^2 L)$$

$$\sim 10^{29} \text{ ergs}$$

where we have taken L and $r = 50, 3$ arcsec.

Energy of the total system is likely 10^{30} ergs or more.

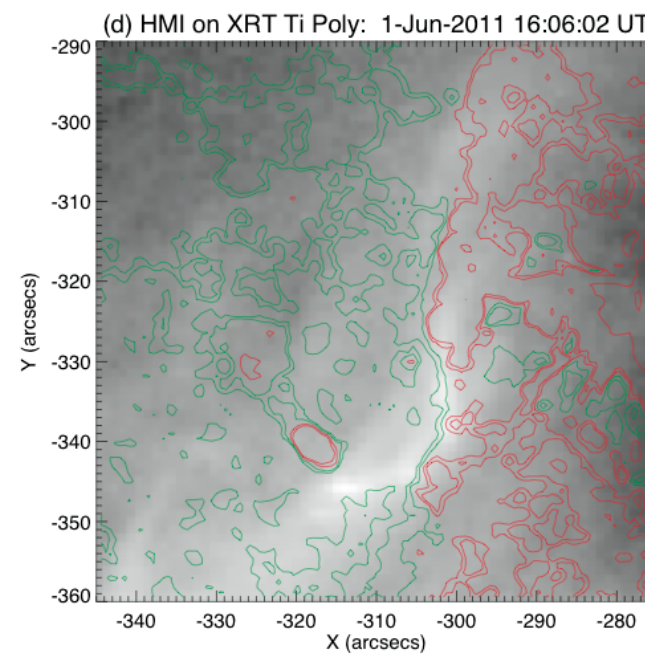
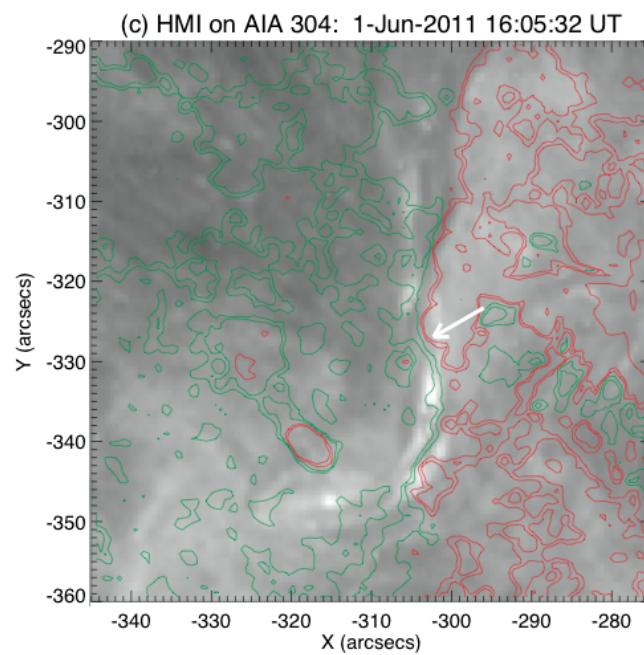
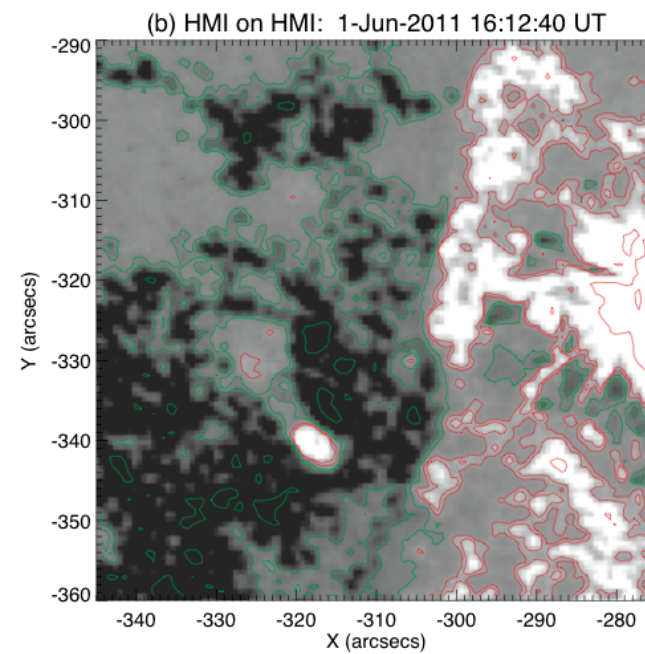
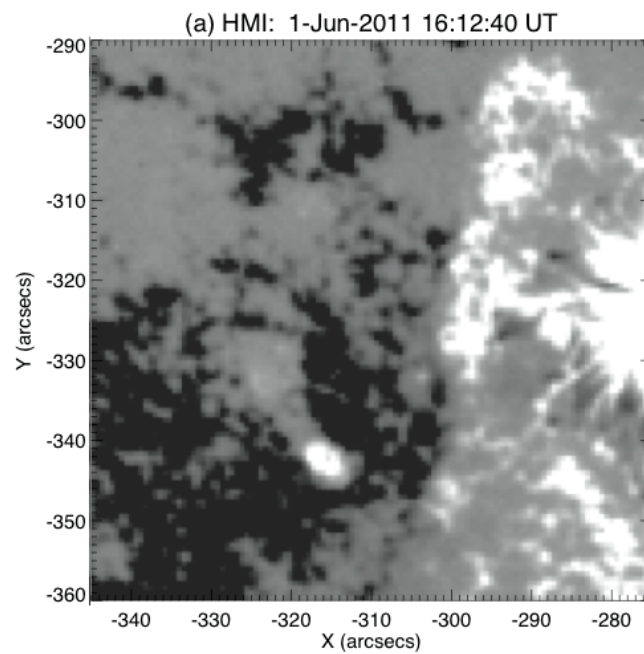
So “no” is answer to question.

Additional energy comes from remainder of sheared large loop, shear (free energy) of second filament, etc. (Normally assumed situation.)

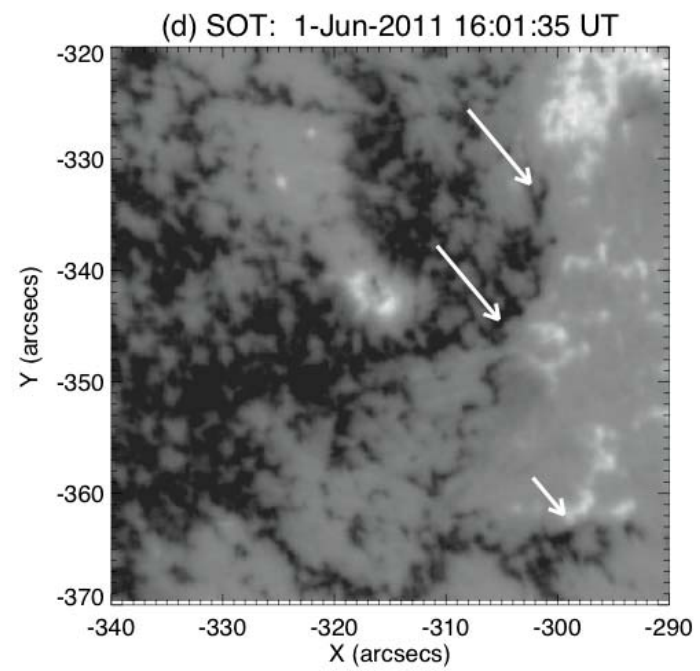
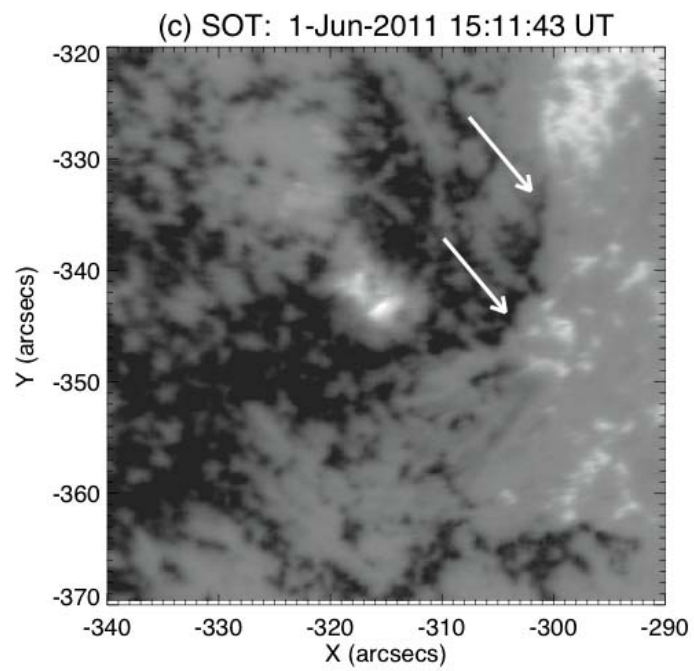
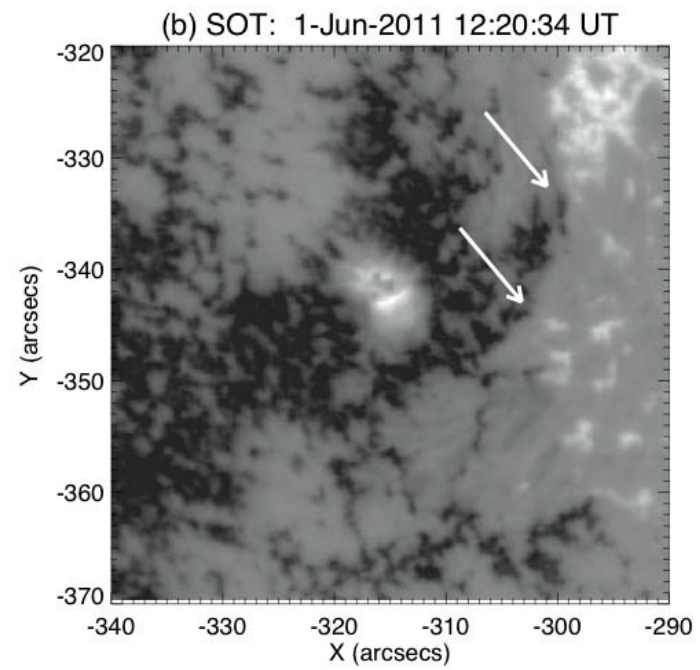
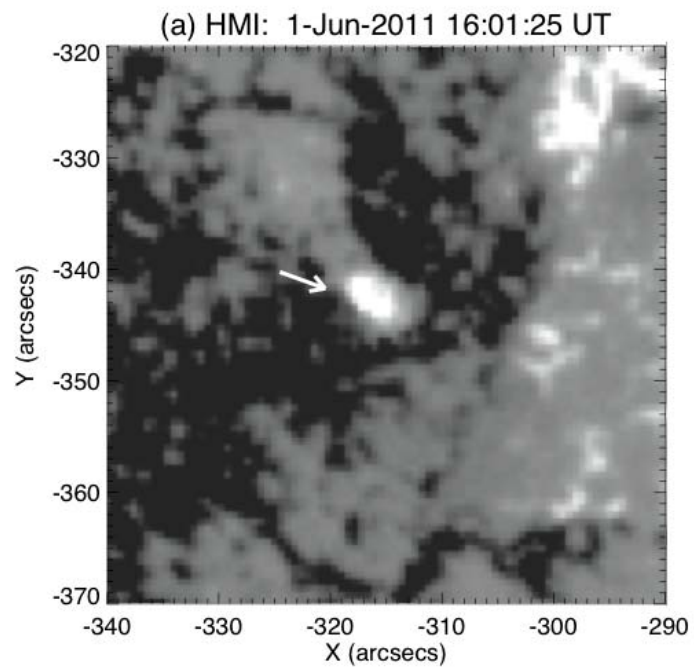
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What causes the initial reconnection at the base?

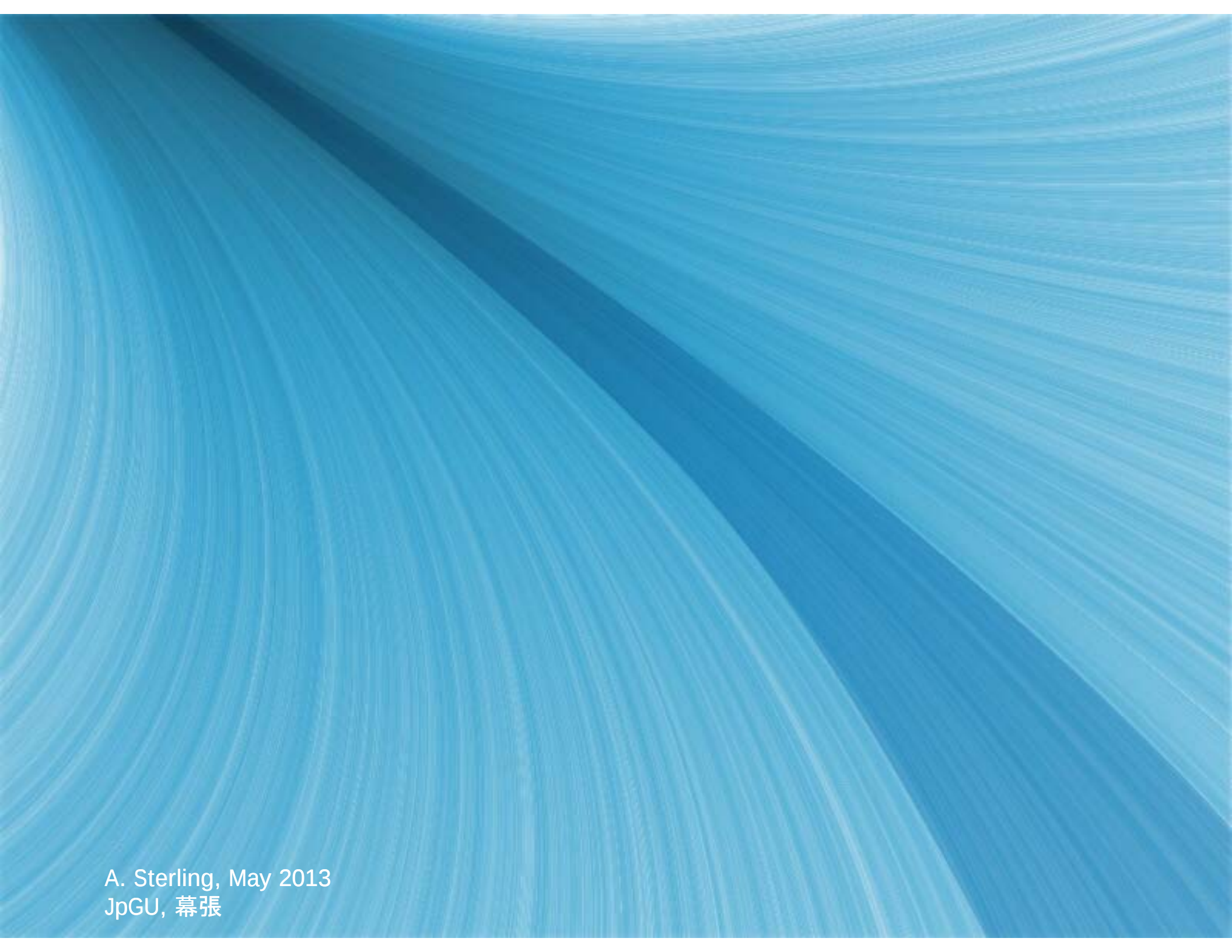


QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.



Conclusions (2011 Jun 1 event)

- ◆ Something leads to reconnection; not totally clear what.
- ◆ Reconnection -> twisted flux rope in ~20 min; episode 1 microflare (flare ribbons; TC) and filament jump.
- ◆ Twist -> writhe, via kink instability; filament-trajectory plateau, ~ 20 min.
- ◆ Writhe -> jump and eruption of filament 1, via instability; episode 2 microflare (flare ribbons; TC). (E.g., Williams et al.)
- ◆ First eruption -> second filament eruption (episode 3 flare ribbons; TC). (E.g., Sterling, Moore; Liu et al.; Torok et al.; Schrijver & Title.)

The background is a solid blue color with a subtle, wavy texture. A prominent, darker blue diagonal band runs from the top-left towards the bottom-right, creating a sense of movement and depth. The overall effect is reminiscent of a stylized ocean or a close-up of a textured surface.

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